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ENGINE COMPRESSION AND CYLINDER LEAKAGE TESTING.

ILLINOIS UNIV., URBANA, VOCAT. AGR. SERVICE

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DESIGNED FOR USE BY HIGH SCHOOL OR ADULT STUDENTS AS TEXT OR REFERENCE MATERIAL, THIS DOCUMENT PRESENTS TECHNICAL INFORMATION NEEDED IN THE FARM POWER AREA OF AGRICULTURAL MECHANICS. IT WAS DESIGNED BY SUBJECT MATTER SPECIALISTS, TEACHER EDUCATORS, SUPERVISORS, AND AN ADVISORY COMMITTEE OF TEACHERS. MAJOR SECTIONS ARE (1) WHAT ARE THE PRINCIPLES OF FOUR-CYCLE ENGINE OPERATION, (2) WHAT ARE THE EFFECTS OF CYLINDER LEAKAGE, (3) HOW IS COMPRESSION TESTED, AND (4) HOW IS A CYLINDER TESTED FOR LEAKAGE. THE SUGGESTED TIME ALLOTMENT IS 1-4 HOURS. TEACHERS WITH A BACKGROUND IN GENERAL AGRICULTURE MAY USE THIS MATERIAL WITH STUDENTS OF BOTH SEXES WHO HAVE AVERAGE ABILITY, AN INTEREST IN AGRICULTURE, AND OCCUPATIONAL OBJECTIVES IN PRODUCTION AGRICULTURE. TABULAR DATA AND LINE DRAWINGS ARE INCLUDED. THIS DOCUMENT IS AVAILABLE FOR 20 CENTS FROM VOCATIONAL AGRICULTURE SERVICE, 434 MUMFORD HALL, UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS 61801. (WB)

ENGINE COMPRESSION AND CYLINDER LEAKAGE TESTING

1. What Are the Principles of Four-Cycle Engine Operation?
2. What Are the Effects of Cylinder Leakage?
3. How Is Compression Tested?
4. How Is a Cylinder Tested for Leakage?

The internal combustion engine burns a mixture of gasoline and air to build up a high pressure in the cylinder that forces the piston down. Then through a connecting rod and wrist pin linkage, the reciprocating motion of the piston is changed to a rotating motion at the crankshaft.

A modern 4-cycle engine has a high compression ratio that provides great power and performance economically. However, the high compression subjects the valves, piston rings, cylinder heads, and gaskets to great combustion pressures. Two-cycle engines also provide economical power, but are not being included in this VAS unit.

The gasoline engine operates like an air pump as it draws in the gaseous mixture of air and fuel and compresses it. It has a four-stroke cycle and produces power only on the power stroke. The other three strokes--exhaust, intake, and compression--function only to prepare the cylinder for the next power stroke. This is called a four-stroke cycle engine, since four separate piston strokes are required for completion of the cycle (Fig. 1). A stroke consists of the piston movement from top dead center (TDC) to bottom dead center (BDC) and therefore represents 180° of crankshaft rotation.

FOUR STROKE CYCLE

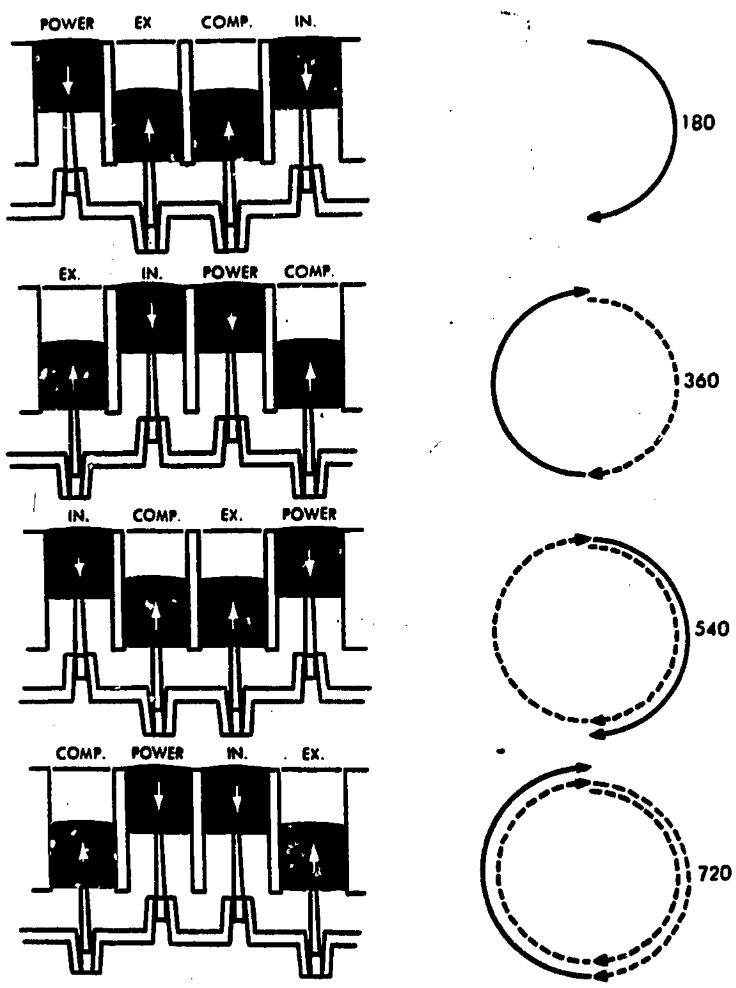

Fig. 1. The four strokes are shown here for a four cylinder engine. Each stroke represents 180° of crankshaft rotation.

1. WHAT ARE THE PRINCIPLES OF FOUR-CYCLE ENGINE OPERATION?

Intake stroke

The intake stroke (Fig. 2) is the first event in the engine's cycle of operation. It begins with the piston at its upper limit or top dead center. Shortly before the piston starts downward on the intake stroke of the cycle, the intake valve starts to open (Fig. 3). The valve is a carefully machined plug that fits in a hole in the top of the cylinder. The hole is called an intake valve port and the edge of the hole (called the valve seat) is carefully machined.

The downward movement or the displacement of the piston creates a space above it which reduces the pressure in the cylinder below that of the atmospheric pressure. Air at atmospheric pressure (14.7 pounds per square inch at sea level) rushes in to equalize the low pressure or partial vacuum.

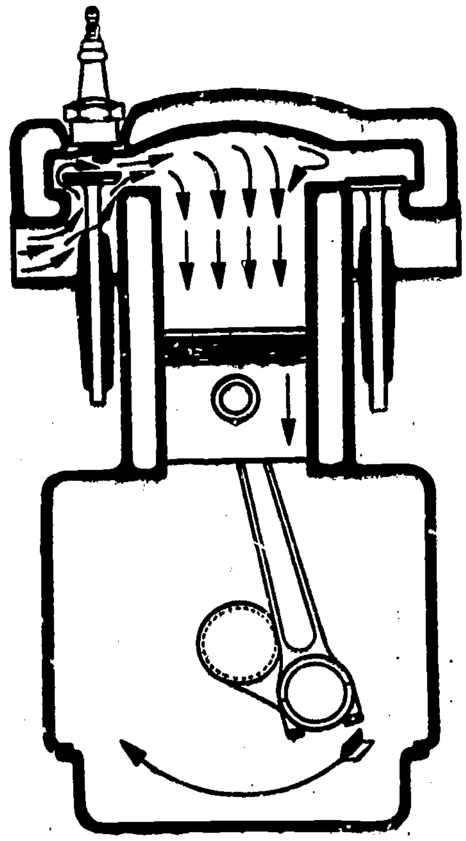

Fig. 2. The intake valve opens and the air-fuel mixture flows in as the piston moves down.

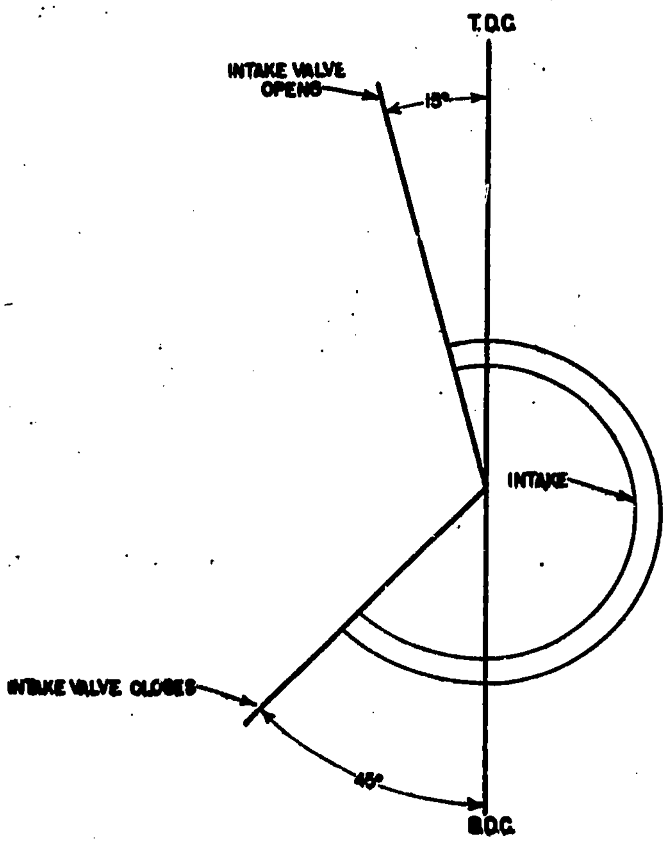

Fig. 3. The intake valve is timed to open before the intake stroke actually begins and closes after the compression stroke has started.

The air, however, cannot move directly into the cylinder. It must pass through an air cleaner, through passages in the carburetor where it picks up a fuel charge, through the intake manifold, and finally around the valve as it passes through the intake valve port. All of these turns and restrictions slow down this air-fuel mixture and increase the time taken for it to reach the cylinder.

If an engine is operating at 3600 revolutions per minute or 60 revolutions per second, the intake stroke (1/2 revolution) takes place in 1/120 of a second. At high speeds this time is reduced still more. It is obvious that anything that can be done to (1) increase the time during which the air-fuel mixture can enter the cylinder, (2) to ease its passage, or (3) to speed up the flow of the mixture will increase the charge taken in. These practices increase the volumetric efficiency of the engine. Volumetric efficiency is explained later.

Compression stroke

The compression stroke follows the intake stroke. As the piston moves upward, with both intake and exhaust valves closed (Figs. 4 and 5), the mixture which entered the cylinder during the intake stroke is compressed to a volume much less than its original volume. All the gases are now compressed in the combustion chamber, the size of which determines the compression ratio of the engine. If the air volume with the piston at top dead center is 1/8 of the air volume in the cylinder with the piston at bottom dead center, then the compression ratio is 8 to 1. The compression stroke compresses the air-fuel mixture to

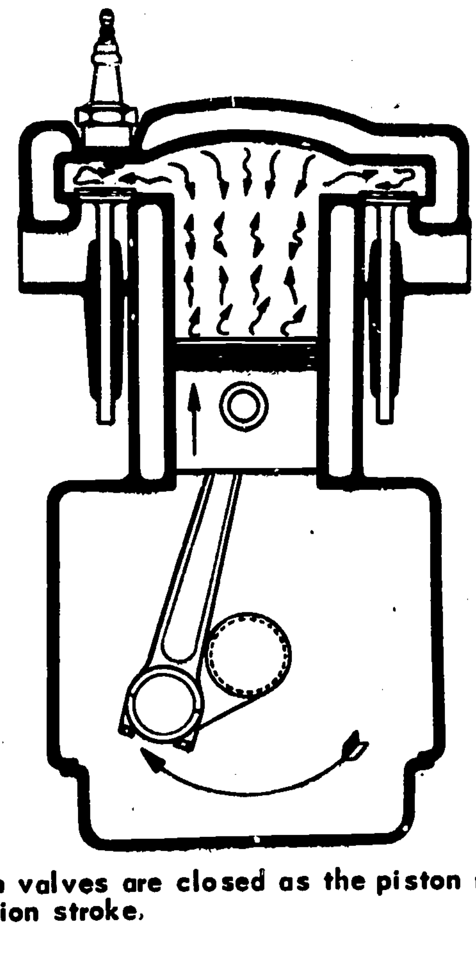

Fig. 4. Both valves are closed as the piston moves up on the compression stroke.

MEMORANDUM

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(Address) 434 Mumford Hall, Urbana, Illinois 61801.

DATE: November 3, 1967

RE: (Author, Title, Publisher, Date) Engine Compression and Cylinder Leakage Testing, VAS 3025. Urbana, Illinois: Vocational Agriculture Service, University of Illinois. 16 p., 1967.

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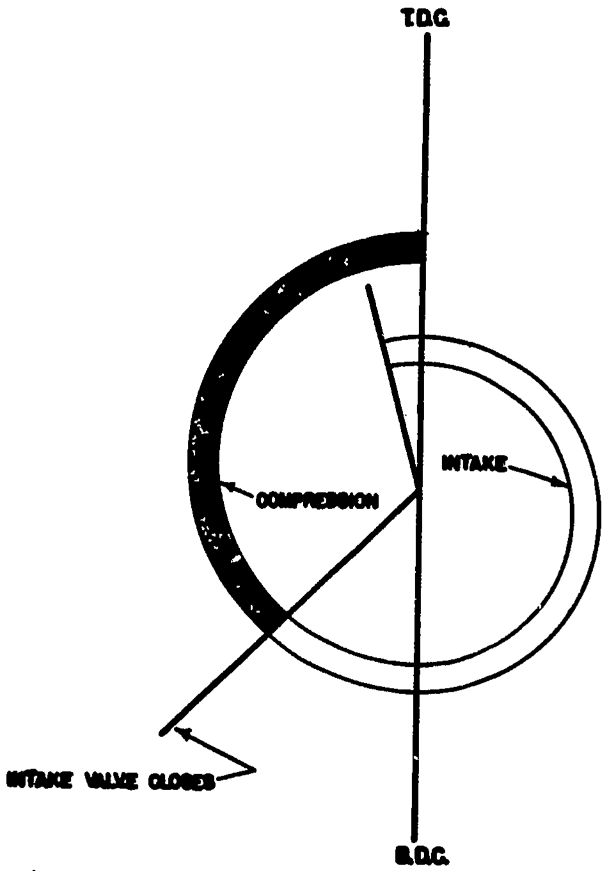

Fig. 5. During the compression stroke, the intake valve closes and the piston moves up, compressing the air-fuel mixture.

approximately 150 pounds per square inch. This makes the gaseous mixture more suitable for efficient combustion.

Power stroke

The intake and compression strokes are followed by the power stroke (Fig. 6). When

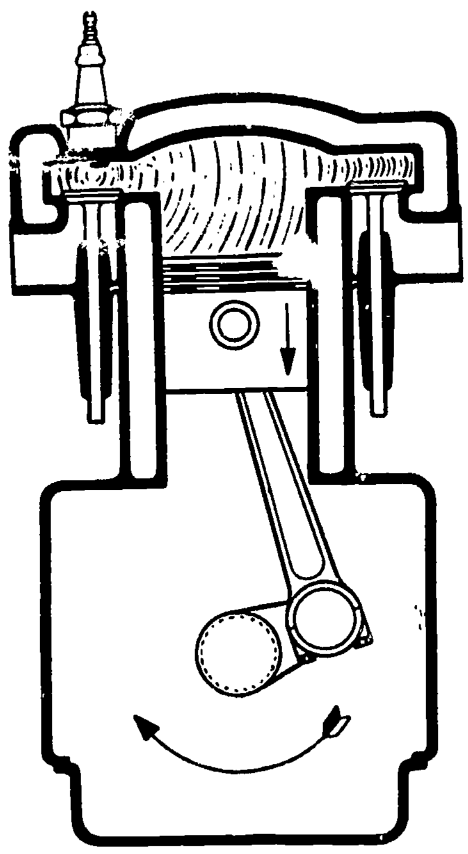

Fig. 6. The ignition system produces a spark that ignites the compressed air-fuel mixture creating the power stroke.

the piston approaches the top dead-center position, a spark occurs across the spark plug electrodes (Fig. 7). This ignites the combustible air-fuel mixture which burns with great rapidity. The exact time that the spark occurs varies with respect to speed and load conditions imposed upon the engine. The rapid combustion of the air-fuel mixture produces tremendous heat which expands the gases and raises the pressure to more than four times the original compression pressure.

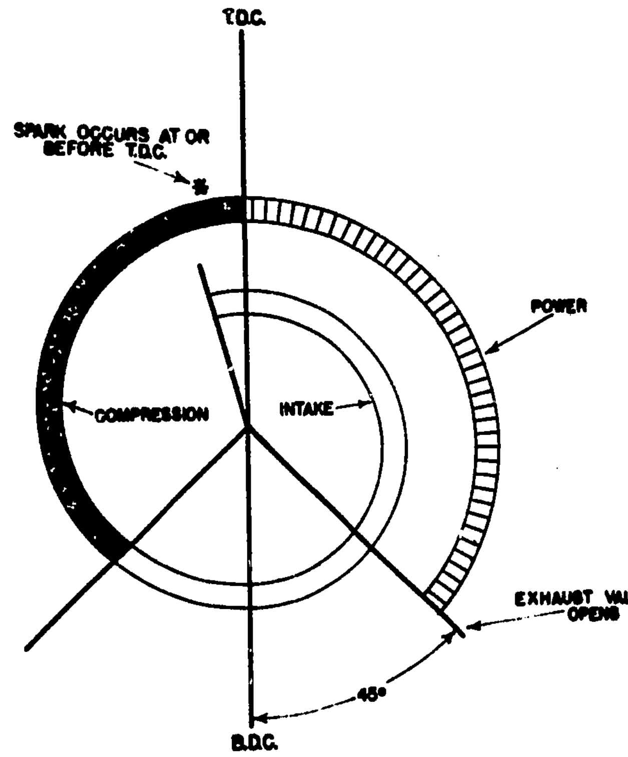

Fig. 7. The spark occurs before TDC and the exhaust valve opens before the piston reaches BDC on the power stroke.

This increase of pressure is exerted upon the head of the piston, forcing it downward in the cylinder. Since the piston is linked to the crank shaft by a connecting rod, the downward motion of the piston is transferred into rotary movement of the crankshaft.

The exhaust valve is opened before the piston reaches the end of the power stroke. This wastes some of the power but it gives the exhaust gases an outlet for expansion and they begin to move out of the exhaust valve port. If the exhaust valve remained closed until BDC, the piston would be opposed by the force that drove it downward and, since it takes time for the exhaust valve to open, considerable power would be lost. Thus, opening the exhaust valve before BDC reduces some of the work done on the exhaust stroke.

Exhaust stroke

The exhaust stroke (Fig. 8) follows the

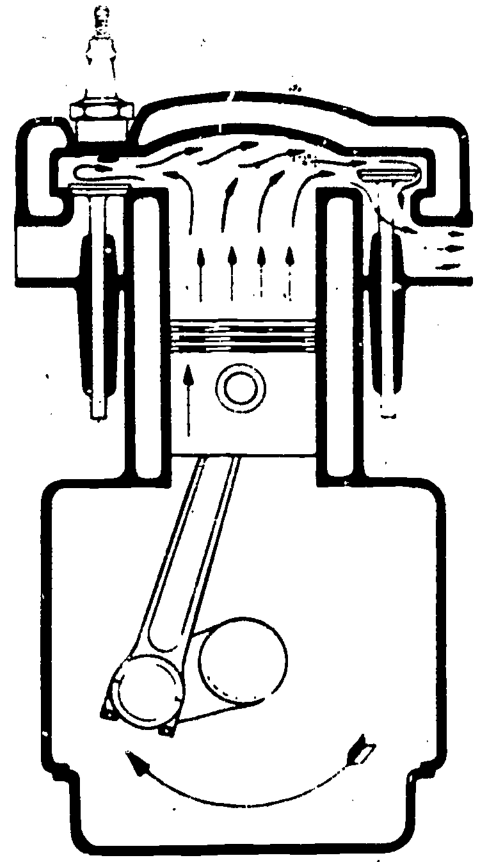

Fig. 8. The exhaust valve has opened and the piston is forcing the burned gases from the cylinder as it moves up on the exhaust stroke.

power stroke. As the piston approaches bottom dead center during the power stroke, the exhaust valve opens. The upward movement of the piston forces the burned gas out of the cylinder and combustion chamber into the exhaust manifold (Fig. 9). When the piston

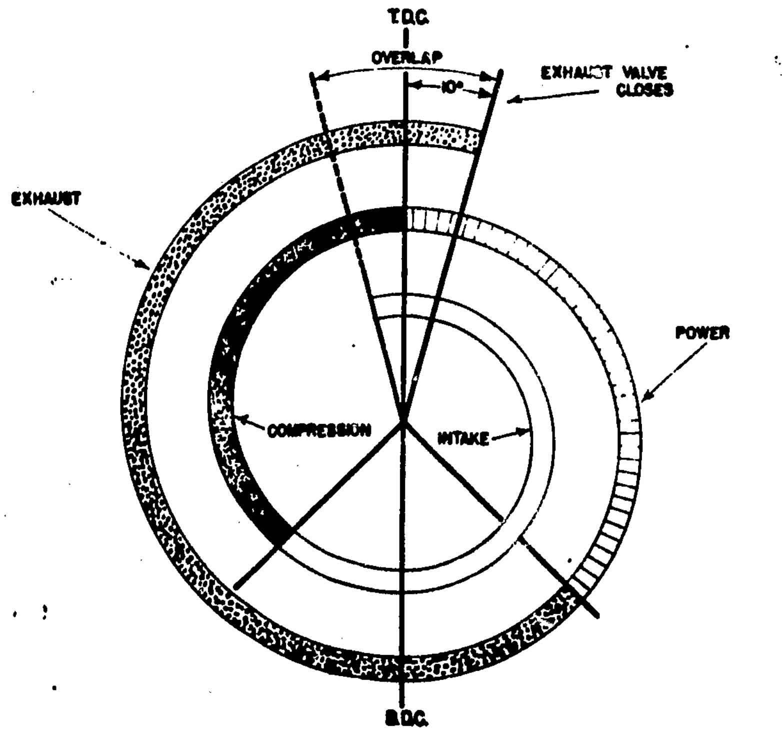

Fig. 9. The exhaust valve will close after TDC and this period when both valves are open is called "overlap."

reaches top dead center or shortly thereafter, the exhaust valve starts to close as the piston starts its downward movement on the intake stroke.

This delayed exhaust valve action is possible because of the relatively low piston speed and travel at top dead center. This condition, with both intake and exhaust valves open is called "overlap" and assures more complete scavenging of the exhaust. If the exhaust valve were closed at TDC, the gases in the vicinity of the exhaust valve port would be retained in the cylinder. As will be seen the piston actually displaces downward a very small amount for the first 10 - 15° movement of the crankshaft.

Engine terminology

As the four-stroke cycles of operation were discussed, several terms were used that may need further explanation.

Piston displacement was discussed in connection with the intake stroke. It is a measure of the quantity of the air-fuel mixture that can be taken into the cylinder on the intake stroke. The formula is: piston displacement = $\frac{(\text{bore})^2}{4}$ x 3.1416 x stroke. If an engine has a 3.5-inch bore and a 3.65-inch stroke, the area of the top of the cylinder is approximately 9.62 square inches and the piston displacement is slightly over 35 cu. inches for one cylinder.

Volumetric efficiency is a measure of an engine's efficiency in taking in the air-fuel mixture. Volumetric efficiency is the ratio between the amount of air-fuel mixture that is actually taken in and the amount that could be taken under near perfect conditions. As this mixture passes through the carburetor and intake manifold, it expands somewhat as it is heated. Therefore, due to the short time involved and the slight heating that takes place, a full charge cannot enter the cylinder. Some of the engineering improvements that have helped to increase the volumetric efficiency at higher rpm are larger intake valves; shorter, larger, and straighter intake manifold passages; and larger or more throats on carburetors.

Newton's law states that matter in motion tends to stay in motion and because of this the intake valve may close some time after bottom dead center to take full advantage of the inertia of this inrushing fuel charge that was started by the intake stroke (Fig. 10). The rush of air-fuel mixture can continue to flow into the cylinder because the piston speed and travel are comparatively slow when the piston is at

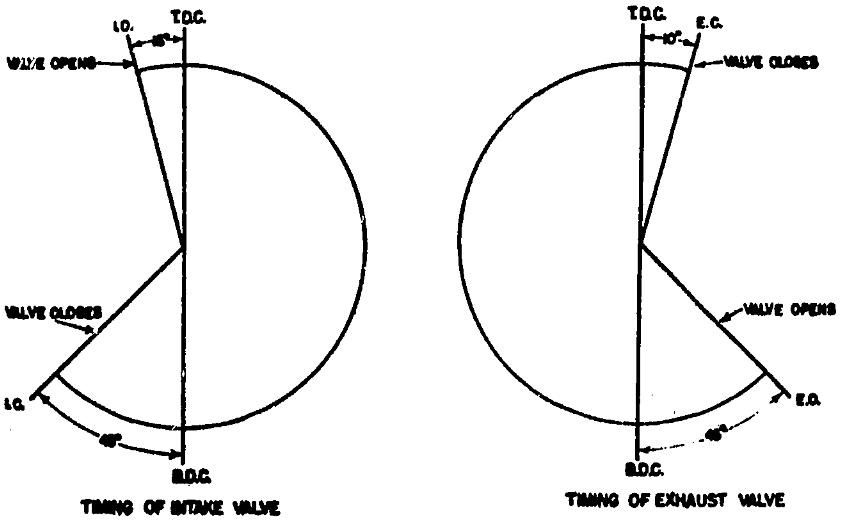

Fig. 10. The intake valve is open for 240° of the crankshaft revolution, including the intake stroke. The exhaust valve is open for 235°, including the exhaust stroke.

bottom dead center, as shown in Fig. 11. There is practically no movement of the piston when the crank arm is near TDC and BDC.

The design of the cam lobe (Fig. 12) permits the valve to stay open longer and this too increases the volumetric efficiency as it increases the amount of combustible mixture that enters the cylinder on the intake stroke.

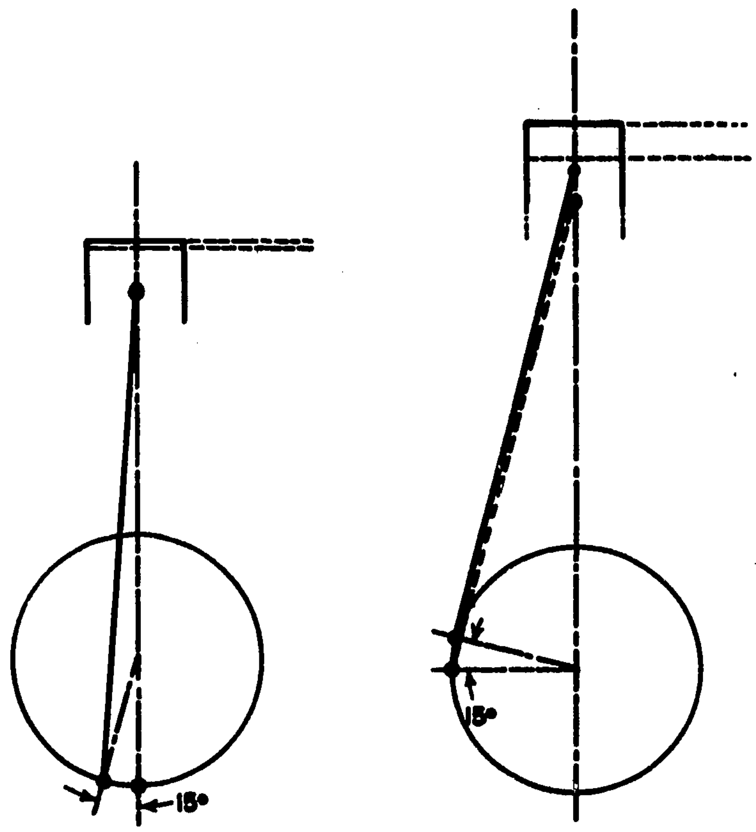

Fig. 11. When the crank arm is at bottom dead center and the crankshaft turns 15° there is very little upward movement of the piston compared to the amount of piston movement when the crank arm is half way between BDC and TDC.

The width of the lobe determines the length of time the valve will be open. If the lobe is wider (nose broader), the valve will remain open longer. If the lobe is narrower (nose more pointed), the valve will be open a shorter

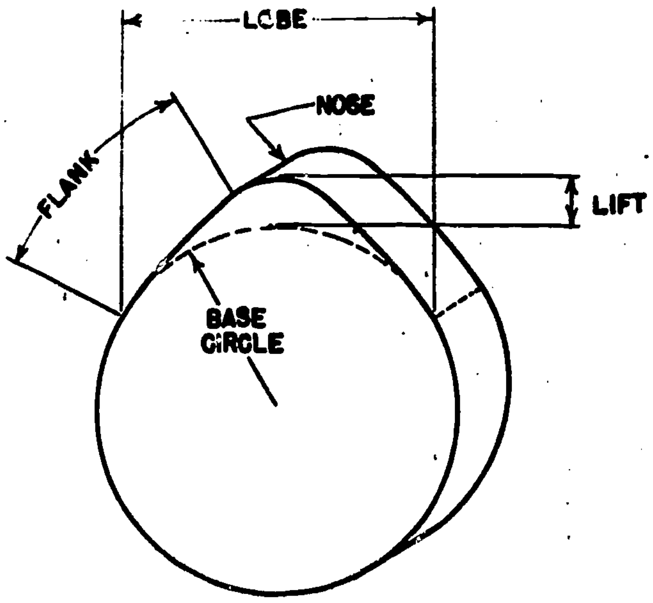

Fig. 12. The design of the cam lobe affects the action of the valve.

time. The lift determines the distance the valve will move as it opens. If the contour of the lobe is too steep, the valve will open and close too rapidly, thus pounding the valve parts and wearing the valve face and seat.

The <u>compression ratio</u> is the total volume of one cylinder with the piston at BDC divided by the volume with the piston at TDC (Fig. 13). Every engine has a small amount of air around the heads of the valves and in the contours of the combustion chamber even when the piston is at top dead center. This is called clearance volume. This volume, plus the piston displacement, is the total volume. As a formula this is expressed as:

$$\text{compression ratio} = \frac{\text{Total volume}}{\text{Clearance volume}}$$

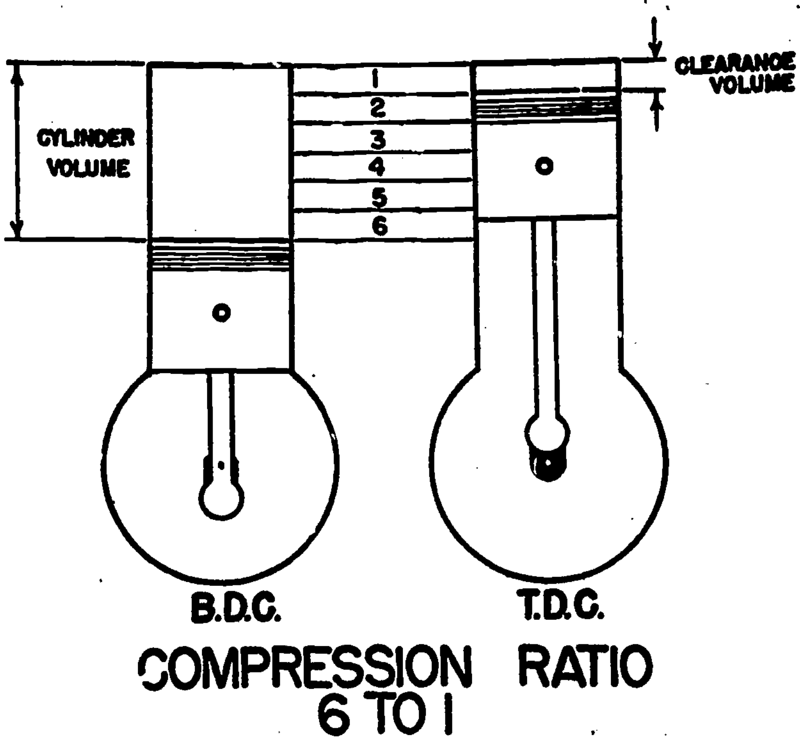

Fig. 13. The relationship between cylinder volume and clearance volume is shown.

Recently, engines have been designed with higher compression ratios. Along with the increase in compression ratio, power and economy have increased without substantially increasing engine weight or size. This higher compression ratio means that there is a higher initial pressure at the end of the compression stroke or the beginning of the power stroke because a larger amount of air-fuel mixture has been compressed. Therefore, at the beginning of the power stroke, when the spark starts the combustion, higher pressures push harder on the piston. These burning gases can expand to a greater volume so there is more push on the piston for a larger part of the power stroke on the piston. In this way more power is obtained from each power stroke.

Piston travel can best be understood by referring to Fig. 14 which shows piston motion. During the first quarter turn, the connecting rod moves down a distance equal to the crank throw. The lower end also moves out this same distance. In other words, the connecting rod which pulls the piston down has two motions, a downward and an outward motion--both of which causes the piston to travel downward. During the next quarter turn, the piston moves downward a distance equal to the crank throw but as the rod comes back to the center line of the piston the inward motion pushes the piston up so the actual downward travel of the piston is less than during the first quarter turn. In the next quarter turn, the piston goes up an amount equal to the crank throw, but as the rod moves out from the center line, the motion pulls the piston down. In the last quarter turn, going up both motions add to the piston travel. On the top half of the crank circle, the in and out motion adds to the piston travel but it subtracts on the lower half.

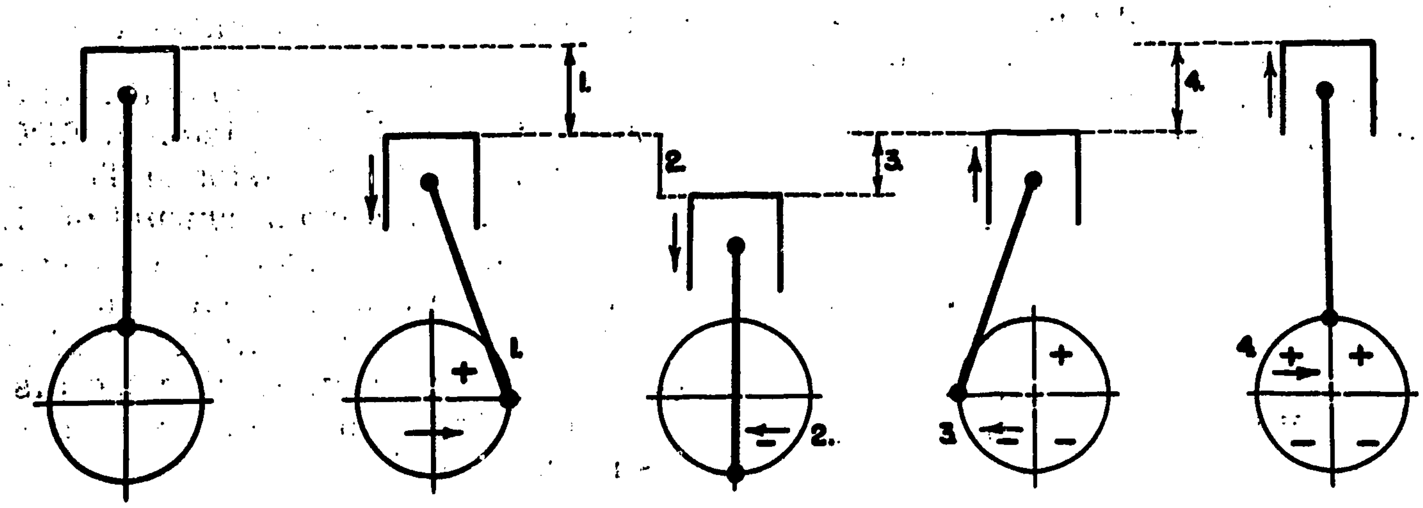

Fig. 14. Piston travel in the first quarter of the revolution is more than in the second quarter. It is less in the third quarter than in the fourth quarter. The reason is because the sidewise motion of the connecting rod adds to or subtracts from the direction of piston travel in a particular quarter of the revolution.

2. WHAT ARE THE EFFECTS OF CYLINDER LEAKAGE?

If there are physical faults in the engine, such as burned valves or a leaking head gasket causing leakage in any of the four strokes, it will reduce the efficiency of the engine. Let us consider the effects of leakage on the functions that take place in a cylinder of an engine beginning with the intake stroke as the air-fuel mixture is drawn into the engine for compression.

Intake-stroke leakage

During the intake stroke, atmospheric pressure pushes the air-fuel charge into the cylinder to offset the partial vacuum created by the downward movement of the piston. It is important that no other openings exist that will permit air, exhaust gases, or water to enter the cylinder and contaminate or dilute the air-fuel mixture, as the engine will not be able to develop its full power potential (Fig. 15).

If an exhaust valve is burned, exhaust gases can be drawn in through this opening and a smaller charge of the air-fuel mixture will enter through the intake valve. The air-fuel mixture will be mixed with the noncombustible gases from the exhaust system and less power will be developed from this diluted mixture.

Fresh air can be drawn into the cylinder through a leaking carburetor gasket, through

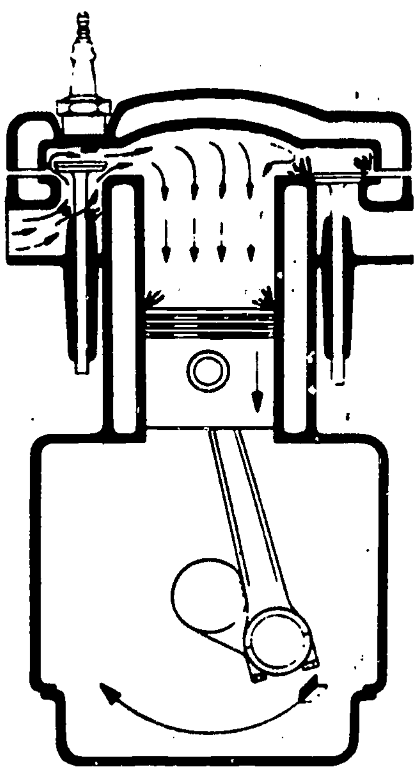

Fig. 15. On the intake stroke, leakage can occur around the exhaust valve, cylinder head gasket, valve guide, manifold gaskets and piston rings.

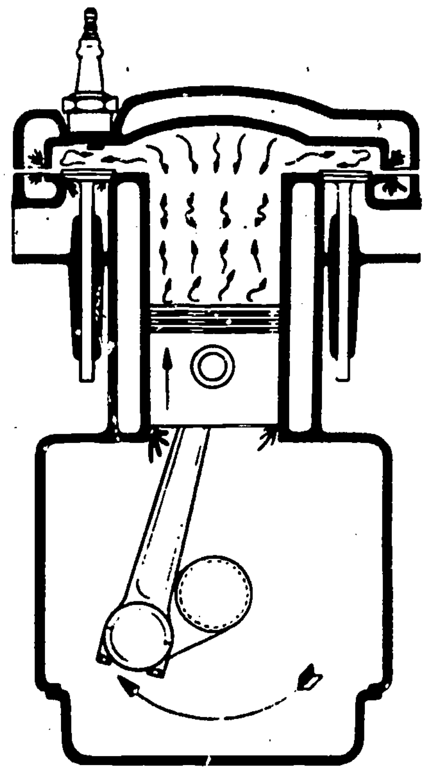

Fig. 16. On the compression stroke, compressed air-fuel mixture leakage can occur through burned valves, leaking gaskets, or worn piston rings.

a worn valve guide, cracked intake manifold, or leaking manifold gasket. This additional air will change the air-fuel ratio, making the mixture lean and the engine will lose power. The lean mixture will burn at a higher temperature and may cause damage by overheating the engine.

If the head gasket is leaking, water may be forced into the cylinder. This moisture will cause the spark plug to misfire and the cylinder may not develop any power. If the piston rings are worn, excessive oil will reach the combustion area, fouling the spark plugs and causing the cylinder to lose power.

Compression-stroke leakage

During the compression stroke, there are normally no openings through which the compressed air-fuel mixture can escape. Should any openings be created by burned valves, leaking gaskets, or worn piston rings, the reduced amount of air-fuel mixture will also reduce the power output of the engine in a proportional amount (Fig. 16).

With leaky valves, the air-fuel mixture that has been drawn in during the intake stroke, will be forced back out on the compression stroke, through the same unwanted openings. This will leave an insufficient air-fuel charge for the power stroke.

If the head gasket is defective, the air-fuel mixture will be forced into the water jacket. This will not only blow the water out of the cooling system, but the coolant will also enter the cylinder during the intake stroke with subsequent loss of power and damage.

If the piston rings are worn, the air-fuel mixture will escape into the crankcase. The fuel will have a tendency to wash the oil from the cylinder walls causing more wear and more leakage. It will also dilute the crankcase oil and further reduce the effectiveness of the lubrication. The engine will not develop full power because of the low compression and excessive friction.

Power-stroke leakage

After the air-fuel mixture is ignited, the expanding gases exert equal pressure throughout the combustion chamber. If the valves are burned, the piston rings worn, or the head gasket blown, these expanding gases will escape and less energy will be available to act on the pistons (Fig. 17). Burned gases will be forced into the intake manifold to contaminate and dilute the air-fuel mixture that is present. These hot gases will "blow by" worn rings, exposing them to high temperature. It will also contaminate the oil in the crankcase.

If the head gasket is blown, the high pressure hot gases will be forced into the water jacket and power will be lost.

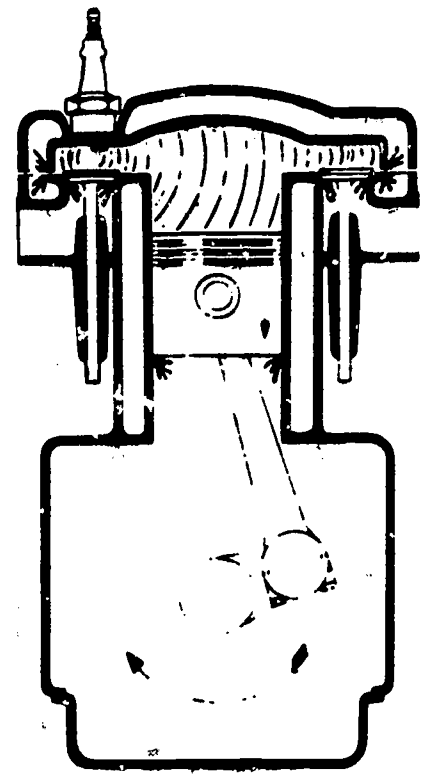

Fig. 17. On the power stroke, energy can be lost through burned valves, worn piston rings, and a leaking head gasket.

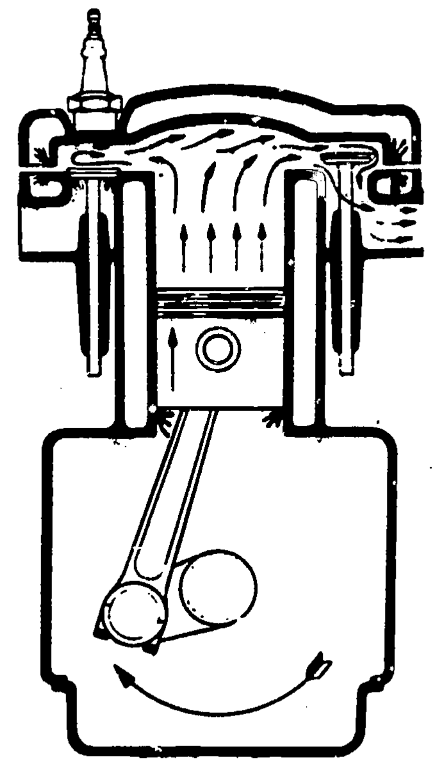

Fig. 18. On the exhaust stroke, burned valves, worn rings and leaking gaskets can cause a power loss.

Exhaust-stroke leakage

As the piston moves up to expel the exhaust gases through the open exhaust valve, some of the gas will pass into the intake manifold if the intake valve is burned (Fig. 18). These gases will also be forced past the worn piston rings and into the crankcase where they will contaminate the oil. If the head gasket is blown, the escaping gases will force the water out of the cooling system causing the engine to overheat.

Cylinder-leakage problems

Leakage at any point in the combustion chamber will have an adverse effect on efficient engine operation.

Valve leakage can reduce engine efficiency in several ways. Leaking intake valves will allow the air-fuel mixture to be pushed back into the intake manifold during the compression stroke and a less dense mixture will be available for the power stroke. During the power stroke, the expanding gases will leak past the burned valves, making less pressure available at the top of the piston. Burned gases will be forced into the intake manifold to mix with the air-fuel mixture. A diluted air-fuel mixture will then be available for the next intake stroke and consequently less power will be developed by the engine. If the exhaust valve is burned, the expanding gases will leak by it and less power will be available. During the exhaust stroke, the burned gases will also be forced into the intake manifold if the intake valve is leaking. This will add more noncombustible gases to the intake manifold.

Any leakage past the compression rings will reduce the power of the engine. During the intake stroke, oil and crankcase fumes will be drawn up into the cylinder and dilute the air-fuel charge. During the compression stroke, part of the air-fuel mixture will be forced into the crankcase and cause oil dilution. The power stroke will force burning gases into the crankcase. These gases will overheat some of the oil, turning it to carbon and the oil will become dark and dirty. The exhaust stroke will force more gases into the crankcase and further contaminate the oil.

Gasket leakage reduces engine efficiency in several ways. A leaking head gasket will permit water to be drawn into the cylinder during the intake stroke. During the compression, power, and exhaust strokes, gases will be forced from the combustion chamber into the cooling system and cause a loss of coolant and the engine to overheat. A less dense air-fuel mixture will be available for the power stroke.

3. HOW IS COMPRESSION TESTED?

Compression tests may be made to determine whether or not the cylinder can compress an air-fuel mixture to a suitable pressure for efficient combustion. Some compression testers also have a built-in solenoid starter control enabling you to crank the engine with the ignition switch "off". This allows one person to crank the engine and read the tests at the same time (Fig. 19).

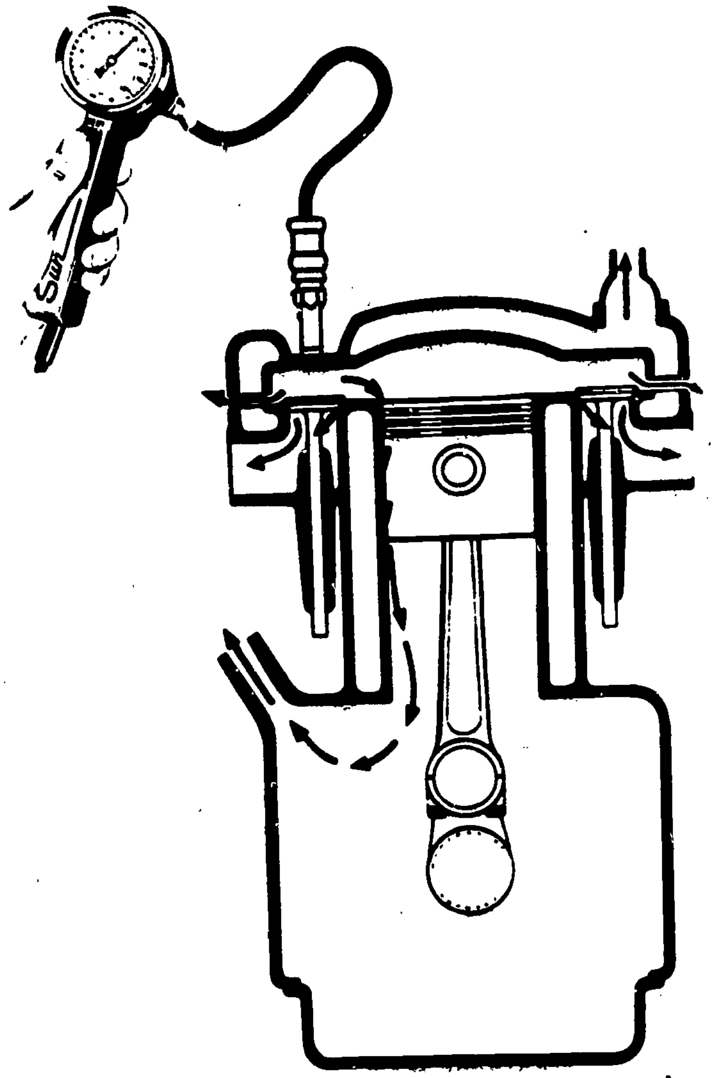

Fig. 19. Interpretation of the compression test results will help determine whether the engine has worn piston rings, leaking valves or leaking gaskets.

Use compression adapter hoses in the spark plug holes because it is impossible to consistently hold a compression tester into a spark plug hole at a uniform pressure, especially when the engine is hot or the spark-plug holes are relatively inaccessible or difficult to reach.

Preparing for the compression test

To perform the test, you will need the following items:

(1) a tachometer, if the engine is not equipped with one,

(2) a deep spark-plug socket, preferably with a rubber spark-plug retainer inside, and a flexible ratchet handle,

(3) an operator's manual or specification manual, (note the way the cylinders are numbered)

(4) a torque wrench,

(5) a compression tester,

(6) a numbered rack in which to place the spark plugs as they are removed from the engine,

(7) an engine test report blank on which to record the test results,

(8) a jumper wire and new spark-plug gaskets.

Be sure the battery is charged and has a high enough capacity and that the starting circuit is in good condition.

1. Run the engine until normal operating temperature is reached. This allows the metals to expand and the parts to assume essentially the same relationship as when the engine is operating.

2. Stop the engine. Remove any components necessary to gain access to the spark plugs.

3. Carefully disconnect the spark-plug wires. Many spark-plug wires are not wires at all. Instead, they have specially treated carbon impregnated conductors that have carefully calibrated electrical resistance. If the conductor is stretched, an open circuit may be created and the plug will not fire properly. Therefore, it is important that these wires be handled properly. If there is some doubt in your mind whether you can replace the wires on the correct plugs, clip a spring-type clothes pin on the wires or use some other method to identify the wire with the correct cylinder.

4. Loosen all spark plugs approximately one turn to break loose any accumulation of carbon formed around the lower edge of the spark plugs.

5. Reconnect the spark-plug wires and start the engine and accelerate to approximately 1000 rpm to blow out loosened carbon flakes. Unless these are removed, they may

become lodged under a valve and cause inaccurate test results.

6. Use compressed air to clean foreign matter from all spark-plug wells to prevent it from dropping into the cylinders.

7. Remove all spark plugs and gaskets or tubes if used, and place the plugs in the numbered rack. (When handling the spark-plug wrench and the hot spark plugs, be careful not to drop them or break the insulators.)

8. Set the carburetor throttle plate to the wide-open position or adjust the hand throttle to the wide-open position.

9. Connect the remote starter-control leads to the starter relay or solenoid switch, (or the solenoid terminal and the battery depending on the type of control and circuit used). On vehicles having 12-volt ignition systems with resister by-pass circuits, use a jumper wire to ground the distributor end of the high tension wire from the coil.

Using the compression tester

1. Select the proper adapter and screw it into the spark-plug port opening, finger tight. Attach the other end of the adapter to the test gauge with the quick disconnect coupling.

2. Move the tester-control switch to crank position and crank the engine continuously until four full compression strokes are completed.

3. Note and record the gauge readings at the end of the first and fourth strokes. The results should be recorded as soon as the test is completed.

4. Release the pressure from the gauge by moving the tester control switch to the vent position.

5. Disconnect the adapter from the tester and move it to the next cylinder.

6. Repeat steps 1 through 4 for all of the remaining cylinders. All cylinders must be tested the same number of strokes to assure accurate readings.

7. Compare the test results with specifications for the engine being tested.

8. Examine the spark plugs for a further indication of engine problems.

9. Replace the plugs, using new gaskets.

10. Use a torque wrench to tighten the spark plugs to the correct specifications when replacing them.

Some general torque recommendations follow:

Thread size	Aluminum heads	Cast Iron heads
10 mm	10 ft. lbs.	12 ft. lbs.
14 mm	22 ft. lbs.	25 ft. lbs.
18 mm	25 ft. lbs.	30 ft. lbs.
7/8 in.	30 ft. lbs.	35 ft. lbs.

Many factors affect cranking speed and will thus affect the test results: condition of starting circuit, cranking ability of starting motor, condition of battery, stiffness of engine, hours of engine use, and temperature and viscosity of the oil.

Compression trouble will nearly always appear as an unbalance among the cylinders. Pressure should not vary more than 10 psi from the highest to the lowest cylinder for low compression engines. For high compression engines the variation allowed may be as high as 50 psi.

Factors affecting the results

Specified compression is obtained by averaging a large number of engines. Results of tests should be accumulated so if specifications for a particular engine are not available, some indication of correct results can be gained from past tests and experience.

Interpreting the results

Worn piston rings are indicated by low compression on the first stroke which tends to build up on the following strokes. A further indication of this is an improvement of the reading for a particular cylinder when oil is added to the cylinder.

Valve trouble is indicated by a low compression reading on the first stroke and it does not build up pressure with succeeding strokes. The addition of oil does not materially affect the readings obtained.

Leaky head gaskets on two adjacent cylinders will produce the same test results as valve trouble. An additional indication of this particular trouble is the appearance of water in the crank case.

Carbon deposits result in compression pressures being considerably higher than specifications would indicate. It is possible for carbon to hide a defect in the cylinder as the deposit will raise the compression ratio of a cylinder which might compensate for leakage.

If leakage occurs at the intake or exhaust valves, gaskets, or rings, it will be impossible to get good engine performance or economy.

To determine the exact cause of abnormal compression test results, more specific information can be secured from the analysis of results of a cylinder leakage test.

4. HOW IS A CYLINDER TESTED FOR LEAKAGE?

In many cases, unsatisfactory performance and rough idle are caused by combustion chamber leakage. Higher compression ratios and the desire for more critical performance and economy demand that a precision method of testing be used. Experience by mechanics, and research by engine manufacturers have established that a compression test may not show up the causes of unsatisfactory performance. The cylinder leakage test is a convenient way to rapidly test the condition of the combustion chamber components for leakage (Fig. 20).

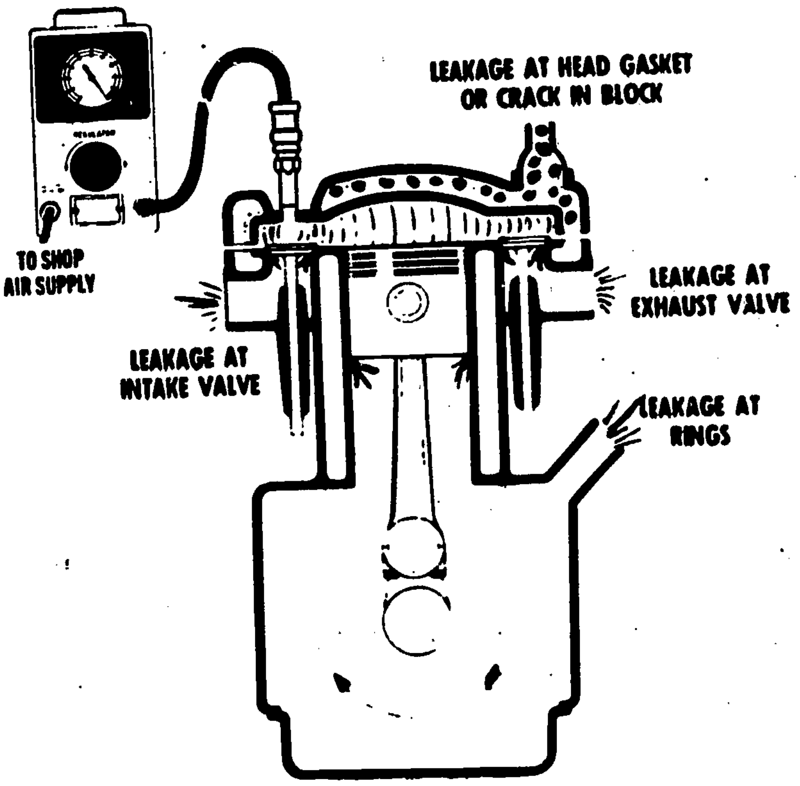

Fig. 20. Interpreting the results of the cylinder leakage test will enable you to determine the location and extent of the cylinder leakage.

Preparing for the leakage test

To perform this test, you will need the following items:

(1) a tachometer if the engine is not equipped with one,

(2) a deep spark plug socket, preferably with a rubber spark-plug retainer inside and a flexible ratchet handle,

(3) an operator's manual or a specification manual, (note the firing order of the engine)

(4) a torque wrench,

(5) a cylinder leakage tester,

(6) a source of compressed air,

(7) a numbered rack in which to place the spark plugs as they are removed from the engine,

(8) new spark plug gaskets,

(9) an engine test-report blank on which to record test results.

1. Run the engine until normal operating temperature is reached so the test is run with parts at the normal operating temperature.

2. Stop the engine. Disconnect spark-plug wires carefully. Many spark-plug wires are not wires at all. They have a carbon train conductor that is specially treated to have a calibrated electrical resistance. If the conductor is stretched, an open circuit may be created and the plug will not fire properly. Therefore, it is important that these wires be handled carefully.

If there is some question in your mind whether you can replace the wires on the correct plugs, clip a spring-type clothes pin on the wires or use some method to identify the wire with the correct cylinder.

3. Loosen all spark plugs approximately one turn to break any accumulation of carbon formed around the lower edge of the spark plugs.

4. Reconnect spark-plug wires and start the engine and accelerate to approximately 1000 rpm to blow out the loosened carbon. This is done to prevent a chip or flake of carbon from becoming lodged between the valve face and seat, temporarily preventing

the valve from seating and causing inaccurate test results.

5. Blow any foreign matter out of the spark-plug wells with compressed air.

6. Remove all spark plugs, gaskets, and tubes and place them in the numbered rack. Be careful when handling the spark-plug wrench and the hot spark plugs that you do not drop or break them.

7. To make it easier to detect the location of the leakage, remove or adjust these items:

(1) Remove the air cleaner,

(2) Remove the crankcase filler cap,

(3) Remove the radiator filler cap. If the coolant level is low, fill to the prescribed level.

(4) Adjust the hand throttle to wide-open position or set the carburetor throttle plate to a wide-open position.

8. Connect a jumper lead from the distributor end of the high tension wire to ground to prevent the engine from trying to start.

9. If a remote starter switch is used to energize the starting motor, be sure it is hooked up correctly. Connect one lead to the high-amperage terminal on the battery side of the solenoid and the other lead to the small control circuit terminal on the ignition switch side of the solenoid.

Calibrating the tester

1. Turn the pressure regulator knob, counter-clockwise, until it turns freely.

2. Connect air supply to the tester. (Do not attempt to remove any fittings from the tester. If additional adapters are needed, add them to the fittings already a part of the tester.) Be sure that a minimum of 70 psi is available but no more than 200 psi is used.

3. Turn the pressure regulator knob clockwise until the gauge reads ZERO. Momentarily connect, then disconnect a test adapter hose. (The pointer on the gauge should return to ZERO. If not, readjust the pressure regulator and recheck the adjustment.)

Using the tester

1. Select the proper adapter and install it in the spark-plug hole of the No. one cylinder. (Check the operator's manual for the cylinder numbering system. It is usually the cylinder at the front of the engine or the one closest to the radiator). Attach a whistle to the adapter in the cylinder.

2. Using either the starter button or the remote starter switch, crank the engine until the whistle sounds. Continue to rotate the engine slowly until the engine timing mark (TDC) aligns with engine timing pointer. Remove the whistle from the adapter. (Note: On some tractors with automatic transmissions, it may be necessary to remove the spark plugs one at a time so the compression prevents the engine from turning over too rapidly.)

3. Remove the distributor cap from the distributor and connect the coil secondary lead to ground with a jumper wire.

4. Mount the "TDC" indicator on the distributor shaft or rotor and chalk mark a suitable reference point on an adjacent surface of the engine which aligns with an applicable mark on the "TDC" indicator.

5. Connect the "indicator light". Clip one lead to the distributor primary terminal and the other lead to ground. Turn the vehicle ignition switch to "ON".

6. Connect the tester hose to the adapter and note the percentage of leakage on the tester gauge. Listen for escaping air (1) through the carburetor, (2) the exhaust pipe, and (3) the crankcase filler pipe. Also check for (4) air bubbles in the radiator.

7. Disconnect the tester hose from the adapter and rotate the engine until the next applicable mark on the "TDC" indicator is aligned with the chalk mark on the engine. The indicator light will glow when the piston is in firing position.

8. Remove the adapter from the cylinder previously tested and install it in the next cylinder in the engine's firing order. The piston in this cylinder is now at "TDC".

9. Examine the spark plugs for a further indication of engine problems.

10. Replace the spark plugs using new gaskets.

11. Use a torque wrench to tighten the spark plugs to the correct specifications when replacing them.

Some general torque recommendations follow:

Thread size	Aluminum heads	Cast Iron heads
10 mm	10 ft. lbs.	12 ft. lbs.
14 mm	22 ft. lbs.	25 ft. lbs.
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7/8 in.	30 ft. lbs.	35 ft. lbs.

Interpreting the results

The gauge readings should be comparatively uniform among cylinders and less than 20% leakage.

If air is escaping through the carburetor, this indicates the intake valve is leaking.

If air is escaping through the exhaust pipe, this indicates the exhaust valve is leaking.

If air is escaping through the radiator, this indicates the head gasket is leaking or there is a crack in the engine head or block.

If adjacent cylinders have a high percentage of leakage, there is an indication of a leak in the head gasket or a crack in the block or head.

If there is a high percentage of leakage in the crankcase, this indicates worn rings or cylinder walls, stuck or broken rings, or a cracked piston. An analysis of the ring and cylinder wall condition should be made with consideration of the case history and age of the engine.

Occasionally, in cases where high percentage of leakage is noted on engines that have been run for a low number of hours the leakage may be attributed to stuck piston rings. It is advisable to treat the engine with a good grade of tune-up or break-in oil for a period of time and then retest it before concluding that the engine be disassembled for major service.

LABORATORY EXERCISES

Be prepared to conduct these laboratory exercises or demonstrations:

1. Assemble the necessary equipment and materials for compression and cylinder leakage testing including:

    cylinder leakage tester
    compression tester
    adapter hose
    spark plug wrench
    spark plug rack (numbered)
    clothes pins or tags to mark ignition wires
    deep socket, (magnetic or rubber spark plug-holding)
    flexible ratchet handle
    compressed air supply and air chuck
    supply of spark plug gaskets
    torque wrench
    operator's manual
    tachometer unless vehicle is so equipped
    engine test report blank

2. Check compression on an engine.
3. Discuss results of compression test.
4. Calibrate cylinder leakage tester.
5. Check cylinder leakage on an engine.
6. Discuss results of leakage test.

Information, illustrations, and assistance in preparing this unit were furnished by Sun Electric Corporation, Chicago, Illinois